Managing Risks Associated with Global Nuclear Energy Expansion: Emerging Challenges and Cooperative Solutions Workshop Summary Report

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Introduction

Global nuclear energy has reached a critical juncture. The footprint of nuclear energy isgrowing and will continue to grow in coming decades to meet increasing global energy demands, desires for energy security, and mounting concerns about climate change. This growth includes construction of reactors in countries new to the nuclear energy enterprise, in addition to expansion of existing programs. The lack of operational experience coupled with weak regulatory systems in some countries raises the potential of a nuclear accident. The expansion of nuclear energy is also met with an increasingly complex threat environment, with threats to nuclear security from non-state actors as well as the continued risks of state proliferation. The trend towards increasingly digitized and networked nuclear facilities significantly expands operational uncertainty and adds complexity to implementing safeguards and security.These factors merit fresh consideration of potential safety, safeguards, security, and cyber (3SC) risks, as well as approaches for managing those risks in an integrated, sustainable, and internationally cooperative manner. In an effort to explore the emerging challenges and cooperative solutions tothe global expansion of nuclear energy The George Washington University Elliott School of International Affairs and Sandia National Laboratories convened a group of more than thirty experts from government, national laboratories, non-government organizations, and academia on May 5th, 2016 at George Washington University to discuss these issues in a not-for-attribution environment. The objectives of the workshop included:

- Taking stock of the current status of global nuclear energy expansion, including current projections, the status of construction projects, emerging reactor and fuel cycle technologies, and other industry developments.

- Examining the changing risk profile for nuclear safety, security, safeguards, and cyber in light of current and emerging threats, new technologies, and new operating environments.

- Critically evaluating the current status of best practices for managing nuclear energy risks including the role of regulatory bodies, human capital development, technology, and international assistance mechanisms.

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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- Identifying policy and technical recommendations for the United States and the international community aimed at sustainably and cooperatively managing risks while facilitating access to the benefits of peaceful nuclear energy use.

This report summarizes those discussions and the recommendations generated.

Session 1. Taking Stock of Global Nuclear Energy Expansion: Risks and Gaps

The first panel session of the workshop examined the expansion of nuclear energy and implications the growth of nuclear energy has on regulatory, safety, security, safeguards, and cyber issues. Despite predictions that the tragic events at Fukushima would halt what had once been termed a nuclear "renaissance," participants noted the considerable expansion and evolution of nuclear energy in both qualitative and quantitative terms. Many countries are building reactors for the first time or are moving aggressively forward on nuclear energy planning, to include Vietnam, Jordan, Saudi Arabia, Malaysia, and the Philippines. Construction of the 4-unit Barakah nuclear power plant (NPP) in the United Arab Emirates is the most dramatic example of nuclear energy expansion in a new user state. While a handful of countries have walked back from nuclear energy after Fukushima, others are proceeding with ambitious expansion – China and India being the two most prominent examples. One participant remarked that this is "a historic moment for civilian nuclear energy." Multiple participants noted the strong structural drivers of energy security, diversification of energy sources, and increasing energy demands of rapidly growing economies while lowering carbon footprints have caused countries to view nuclear energy as a potential solution.

The growth of reactors in new countries also introduces the potential risk of reactors operating in novel environments where corruption, weak rule of law and regulations, and political instability could be more commonplace. Examining how these new environments raise concerns from nuclear safety, security, safeguards and ultimately affect US national security interests is an area that needs to be addressed in more detail.

Beyond the growth of nuclear energy, participants also noted the importance of the expansion of new and existing suppliers. South Korea's winning bid for the Barakah NPP contract is emblematic of the role played by new supplier states in nuclear energy expansion; western technology suppliers do not enjoy the market dominance they once held. Besides South Korea, China is also poised to become a major player in nuclear energy markets, with the potential to offer substantial economic and political incentives to prospective customers. Existing nuclear energy suppliers are seeking to expand into new (smaller and less developed) countries. Russia's strategy to build, finance, and take-back spent fuel is illustrative of the multifaceted efforts existing suppliers are offering to secure commitments.

While high-output Generation III/III+ reactors currently dominate expansion plans, both among existing and new users, significant progress has been made in the development of small modular reactors (SMRs) that may be attractive in certain emerging markets. However, one participant challenged this conventional wisdom. He argued that not only are SMR designs much less efficient in fuel demands

compared to light water reactors, they also produce more spent fuel – with higher plutonium content. The availability of infrastructure (including sufficient water) and the increased complexity of achieving siting approvals for multiple small reactors may also drive countries towards older, larger designs. Fuel cycle technologies like laser isotope separation and pyroprocessing may also contribute to a nuclear energy future that is a technological departure from the past.

It was the growing risks of cyber on nuclear energy that attracted the attention of participants. One participant stressed we have created systems that are more complex than we can manage and this creates risk. Cyberattacks have the potential to compromise security – through theft and sabotage – but there are still major shortcomings in the international regulations and technical expertise needed to effectively manage and mitigate the risk.

Some participants stressed the new operating environment will place additional burdens on nuclear regulators, particularly the US Nuclear Regulatory Commission (NRC), whose technical credibility is well respected worldwide. This pressure is occurring within an environment where the NRC is downsizing and becoming more efficient, while also preparing for anticipated licensing of advanced reactors. This reality makes the task of providing effective regulation, balancing encouraging innovation, and providing effective oversight all the more challenging.

Session 2. Technical Challenges and Responses for Managing Nuclear Risks

The second panel addressed the technical and policy dimensions of nuclear safety, security, safeguards, and cyber challenges in greater depth. On nuclear safety, recent developments have been greatly influenced by the events at Fukushima – particularly the recognition that operators need to be prepared for high consequence events that might exceed predictions. The NRC FLEX program has engaged with operators domestically to strengthen response planning and emergency preparedness, preposition resources, and ensure adequate communications.

The vulnerabilities and potential failure modes associated with digital instrumentation and control systems are also receiving increasing attention, given their importance in new reactors and retrofits to legacy designs. These systems raise particular concern from a cyber security standpoint; further research is needed to understand – from a system of systems standpoint – the full scope of threats, vulnerabilities, consequences, and ultimately solutions for managing the cyber threat.

The United States Government (USG), through the Department of Energy and other agencies, continues to focus on global capacity building for nuclear security. Discussions suggested that given the scope of the problem, there is need for a clearer sense of prioritization, both in terms of understanding which international partners have the greatest need for assistance, the technical areas that should be prioritized for research and development, and the role of US agencies. International partners would further benefit from assistance in setting their own internal nuclear security priorities, rather than waiting for external direction. As partners develop capacities and implement security systems, there is need for verification and certification processes to evaluate capabilities and identify needs for further improvement.

Technical R&D and capacity development requires resources. The discussion emphasized that across nuclear safety, security, and safeguards, implementers and assistance providers are stretching to meet increasing demand with budgets and human resources that have either stagnated or in some cases shrunk. The International Atomic Energy Agency (IAEA) safeguards system for example, must contend with expected growth in facilities and material stockpiles (particularly in the form of spent fuel), along with more exceptional commitments like the Joint Comprehensive Plan of Action for monitoring Iran's nuclear program. Technical process improvements in the form of better data management and integration, developing states' capacities for more streamlined and accurate reporting, and the State-level safeguards approach[1] may help to manage some of these burdens.

Breakout Group Sessions

In the afternoon, workshop participants divided into facilitated breakout groups to explore issues from the morning in more depth, highlight additional risks or priorities that may have been overlooked, and develop recommendations.

Discussions in the first breakout group initially highlighted the role of the US nuclear industry. Concern was expressed that a lack of US commercial success (both domestically and abroad) will not only diminish the industry's viability, but undermine US influence on global nuclear energy expansion writ large – especially by comparison to competitors who can more seamlessly blend politics and commerce through state-owned nuclear power companies. New US reactor designs like the Economic Simplified Boiling Water Reactor (ESBWR) have been slow to reach markets owing to a combination of regulatory hurdles, prohibitive startup costs, and competition from other energy sources. Inability to solve the nuclear waste problem is a further impediment to nuclear energy expansion not only in the United States, but also abroad given that few operators have found a solution (though some, like Russia, are offering spent fuel "take back" as a commercial incentive).

On the issue of regulatory challenges, participants noted that the lack of internationally accepted universal reactor safety and licensing standards is a potential impediment to both US market access (by virtue of a less-than-level playing field favoring competitors whose licensing standards may not be so stringent) and to ensuring that expansion takes place in a safe and secure matter. However, there is also concern from a policy standpoint as to whether or not a universal safety standard would actually be desirable, or merely promote a "box checking" mentality on the part of nuclear energy users.

Discussions also highlighted a lack of global capacity for responding to exceptional, high consequence incidents like Fukushima. There is no parallel to the US FLEX approach elsewhere in the world; the United States is capable of providing valuable technical support on a case-by-case basis (as it did for Fukushima), but it would be preferable if US partners possessed autonomous capacities for emergency planning and preparedness. Similar concerns extend to the cyber realm, where it is not clear that foreign

[1] "The IAEA develops a State-level safeguards approach (SLA) for States on the basis of a structured, technical method used to analyze the plausible paths by which nuclear material could be acquired." https://www.iaea.org/safeguards/safeguards-in-practice/development-of-a-safeguards-approach.

nuclear aspirants are sufficiently factoring cyber risks into nuclear energy planning and implementation. For example, in many cases operators may not have access to the source code used in critical reactor control systems. Having access to the source code would allow for inspection, identification, and mitigation of potential vulnerabilities and would help prevent malicious code injection. While assessing the code may be expensive and requires specific expertise to be effective at reducing cyber risks, it would be a strong step towards reducing risks from the supply chain.

Discussions in the second breakout session began by participants stating that one of the most significant risks facing the global expansion of nuclear energy was the potential of a Fukushima like incident occurring in a country without a safety culture, a lack of regulatory oversight, or counterfeit/fraudulent parts. It was feared that such an incident could take down the nuclear industry across the world. Generally, the group agreed that the role of a safety (or security) culture was critical to mitigating risks. However, there is also the concern that the focus on safety risks can cause risks somewhere else, and that programs need to be cautious of and try to better understand the unintended consequences of addressing only one part of the nuclear enterprise.

Several participants noted one way of improving international safety and security standards is through providing greater support for exporting US designs – particularly SMRs. They argued US suppliers are being outcompeted by supplier countries like France and Russia who are able to marshal significant governmental support for their commercial efforts. It was suggested that decreasing the time it takes for the NRC to approve new reactor designs as well as encouraging the Department of Commerce to take a more active role when other USG agencies discuss safety, security, or safeguards with foreign countries could help US suppliers be more competitive. Outside of efforts to support exporting US designs, participants offered several other avenues where the US could advance its nuclear safety, security, and safeguards goals. These included: advancing Nuclear Suppliers Group (NSG) standards of nuclear security, utilizing the entry into force of the IAEA Convention on the Physical Protection of Nuclear Material (CPPNM) amendment to promote nuclear security, and promoting strategic energy planning – to include alternative energy sources.

Finally, discussions focused on the strengths and weaknesses of USG outreach programs. Overall participates stressed that US programs are well respected internationally. In particular, the national labs and NRC are trusted and respected for their independence (non-promotion of specific technologies) and scientist-to-scientist engagement, and long-term capacity building. Yet, there was a clear recognition that US outreach programs still need better coordination.

Recommendations

The following policy and technical recommendations represent the sense of the workshop chairs, reflecting participant contributions.

Recommendation 1: US outreach should enable countries to realize the economic and energy security benefits of nuclear power while ensuring adequate global safety, security, safeguards, and cyber protections and institutionalize a more integrated approach to international outreach.

US outreach programs focus, to a large degree, on preventing or mitigating the consequences of failures in safety, security, and safeguards implementation. However, it is important not to lose sight of the fact that international partners are pursuing nuclear energy for its benefits, including generation of electrical power for economic development, diversification of energy sources for greater security, and the reduction of carbon footprints. If the United States is to maintain influence in shaping the direction of nuclear energy expansion, it must clearly emphasize the role outreach plays in enabling these benefits. In some cases, achieving this balance may simply be a matter of messaging, emphasizing the fact that a safe, secure, and safeguarded nuclear energy enterprise will ensure nuclear power's economic viability well into the future. In other cases, this balance may need to be a more explicit consideration in the design of new safety, security, safeguards, and cyber systems and approaches, as reflected in recent initiatives to make the IAEA safeguards system more streamlined and efficient.

US outreach programs on safety, security, and safeguards have historically operated independently of one another, at least partly under the assumption that they are governed by different international frameworks, require different technical resources, and target different audiences. Discussions suggested that these assumptions are increasingly untenable given the intersection of risks across these domains. For example, the artificial divides between security and safety quickly break down if an adversary manages to compromise key reactor safety and containment systems; response planning and resources often intersect (and sometimes may even conflict) across these domains. Accurate material accounting and reporting is an issue that cuts across safety, security, and safeguards. Cyber-attacks are particularly unlikely to discriminate between boundaries. These intersections beg for a more integrated approach to safety, security, and safeguards risk assessment, mitigation planning, and program implementation.

More practically, foreign partners rarely silo programs in a manner that mirrors the US government; the same offices and personnel may have responsibilities across multiple (or all) domains. This creates challenges in terms of maintaining consistent messaging across programs and preventing "engagement fatigue" from repeated US visits and training courses (on top of outreach by IAEA and other foreign entities). Steps have been taken in recent years to improve coordination through the National Security Council and regular interagency processes. Further coordination within the US government, possibly through creation of a dedicated program integration office, could help address these issues and facilitate more efficient engagement targeted at clearly defined partner needs.

Recommendation 2: Empower the US nuclear industry and leverage its potential as a mechanism for influencing nuclear energy expansion.

Foreign technology suppliers currently dominate the market for projected nuclear energy expansion. US competitors benefit from substantial state investment in nuclear power companies, allowing for more flexibility in bidding and the ability to couple NPP sales with other diplomatic and economic incentives. These competitors may not place similar emphasis on 3SC commitments and best practices, potentially lessening US influence in these areas.

Although the USG cannot replicate the public/private vending model of its competitors, there are steps that can be taken to empower US industry and leverage its potential for positively influencing foreign nuclear programs. These steps could include partnering more closely with industry to promote global standards on 3SC best practices, finding better ways to integrate and promote the nuclear industry in US economic outreach, and facilitating access to US domestic markets (and by extension, foreign markets) through more efficient licensing processes of new reactor designs and implementing a solution for long term spent fuel management.

Recommendation 3: Continue to support safety, security, and safeguards capacity building, emphasizing promotion of self-sustaining capabilities, and development of robust organizations and organizational cultures.

The United States continues to play a valuable role in promoting best practices and building foreign capacities for safety, security, and safeguards implementation. Emphasis should continue to be placed on development of self-sustaining capacities among assistance recipients that reduce dependence on external sources of training and technology assistance. The Nuclear Security Centers of Excellence (COE) are one model for such an approach, providing regional hubs for training and best practices sharing that can meet the needs of multiple countries. The current COE model largely emphasizes security and safeguards, but the role of these centers can be expanded to include safety and cyber capacity building.

The promotion of independent and reliable national regulatory organizations is equally important, both for countries with no prior history of nuclear implementation, and those where a history of regulatory inconsistency is coupled with a persistent belief in the improbability of accidents ("it can't happen here") or optimistic assessments of emergency preparedness ("we are prepared for all contingencies"). The NRC, which is still widely recognized across the globe as the "Gold Standard" for regulatory best practices, has a potentially crucial role to play in this regard. Traditional approaches to safety, security, and safeguards engagement emphasize regulatory awareness, technical knowledge, and procedural mechanisms. These areas remain important and relevant, but workshop discussions also emphasized the salience of organizational "cultures." It is one thing for personnel to learn 3SC best practices, but quite another for those individuals (and their organizations) to collectively recognize the significance of the risks they face, embrace the mission space, and commit to accountable implementation.

Recommendation 4: Strengthen and utilize international instruments to promote 3SC best practices.

International agreements, standards, and best practices support US engagement by conferring multinational legitimacy to US outreach priorities and establishing an independent "baseline" of expectations regarding conduct of the nuclear enterprise. This baseline is probably most well developed in regards to nuclear nonproliferation, which benefits from six decades of international dialog and implementation experience, as well as a robust regime of binding treaties and agreements. The baselines for nuclear safety and security are arguably less institutionalized, though notable strides have been made in recent decades (evidenced by entry into force of the IAEA Convention on the Physical Protection of Nuclear Material (CPPNM)).

Efforts should be undertaken to further augment and strengthen available international instruments, particularly on safety and security. While binding commitments and treaties may not be realistic or desirable in every situation, agreed upon best practices and codes of conduct – in combination with related outreach and capacity development – help to reinforce 3SC norms. Moreover, in a world where the United States faces increasing competition for influence on civilian nuclear energy development, these instruments can help to influence a more level playing field in which suppliers and recipient states are held to a universally understood set of expectations.

Recommendation 5: Elevate cyber as a mission area equivalent to safety, security, and safeguards.

The significance of cyber threats has grown to such an extent that the issue can no longer be treated as a secondary component of existing safety, security, and safeguards programs; it merits systems analysis and systems solutions that cross the boundaries of these domains. This should begin with a comprehensive assessment of cyber risks to the nuclear enterprise addressing threats and vulnerabilities to reactor and fuel cycle technologies. While studies have been conducted on these issues by both the US government and non-government organizations, discussions suggest that much work remains to be done, particularly in regards to understanding risks associated with foreign-origin systems, emerging technologies, and retrofits to legacy systems. A comprehensive risk assessment would serve as the basis for prioritization of both subsequent technical R&D and outreach to international partners promoting cyber risk mitigation approaches and best practices.

Discussions indicate that cyber capacity building requires particular attention. Foreign partners increasingly recognize the significance of cyber risks, but in many cases lack both organizational mechanisms and expertise to manage the problem. A strikingly large number of both current and projected nuclear energy states lack basic regulatory provisions for cyber risk management. Cyber is sometimes an afterthought in contracting with foreign technology vendors. Experts with critical skills for cyber prevention, detection, and response are also in short supply. These are all areas where the United States can contribute to global capacity building, assuming dedicated resources and a coordinated approach.

Recommendation 6: Develop global capacities for safety and security emergency response and consequence management.

Fukushima highlighted the need for more robust planning, as well as prepositioned and readily deployable resources and expertise to support emergency response and consequence management – particularly in situations where a catastrophic nuclear safety event could exceed onsite or even in-country capacities. In the US context, the NRC implemented its FLEX[2] strategy that includes, among other measures, prepositioning of response resources and training to prepare for such events. Unfortunately, there has not been a push at the international level to develop similar capacities elsewhere in the world.

[2] "The diverse and flexible coping capability, or 'FLEX,' builds on earlier safety steps by providing an effective and efficient way to make U.S. nuclear energy facilities even safer." http://safetyfirst.nei.org/industry-actions/flex-the-industry-strategy-to-enhance-safety/.

Capacity development might take place at the national level, with the United States and its international partners assisting countries in developing their own strategies and capabilities supporting emergency response and consequence management. It could also take the form of building shared, regional capacities and resources that support multiple nuclear power operators; indeed, this may be a more realistic approach for new nuclear energy states whose resources may be limited. Such capacities would benefit response and consequence management for nuclear security events, especially if nuclear security contingencies are incorporated in the planning process.

Recommendation 7: Convene US nuclear energy stakeholders on an annual basis to facilitate sharing of programmatic insights and outreach lessons learned.

Finally, discussions indicated that from more regular meetings with US nuclear energy stakeholders should be conducted, like the one held on May 5th, 2016. It is rare for so many stakeholders – including the US interagency, industry, academia, and non-government organizations – to be represented at one table in open discussion. Beyond networking, such meetings help to increase situational awareness of programmatic activities; promote understanding of challenges across safety, security, and safeguards domains; and highlight emerging risks. It is recommended these meetings continue to be held under not-for-attribution conditions to facilitate an open dialog, and insights be published and disseminated to outreach stakeholders.

While the challenges cited appear daunting, the United States is still uniquely equipped to positively impact the direction of nuclear energy expansion by virtue of its global influence, resources, technical capacities, and the international reputation of its regulatory and scientific institutions. US outreach programs can rightly claim a strong record of success to date in building global capacities for safe, secure, and safeguarded peaceful uses of nuclear energy. Implementing the recommendations from this meeting should further augment and enhance that impact in the decades ahead.